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THE EFFECT OF WINDSCREEN BOWS AND HUD PITCH LADDER FORMAT ON PILOT PERFORMANCE DURING SIMULATED FLIGHT

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During the upgrade of the F-14 to the F-14D, pilots have expressed their concerns regarding the obscuration of the forward field-of-view due to the new Head-up Display (HUD) supports in conjunction with preexisting windscreen bows. An additional issue involves the proposed use of the HUD as the primary flight reference instrument. The HUD pitch ladder has been criticized for not providing enough information to enhance recovery from unusual attitudes. The purpose of the present study was, therefore, twofold: (1) to measure the levels of "target" detection with and without windscreen bows, and (2) to measure unusual attitude recovery performance using two different HUD pitch ladder formats – Standard versus Enhanced. During simulated flight, twelve subjects were required to make visual detections of enemy aircraft with and without the windscreen bow. Additionally, subjects were required to recover from various pitch/roll combinations. (Continued)

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It was clear that removal of the windscreen bows improved target detection performance. Results of the obscuration study showed that in the first five seconds into the flight 80 percent of the targets were detected with bows off, while only 60 percent were detected with bows on. Evaluation of performance with the two HUD pitch ladder formats revealed that, at severe negative pitch attitudes, there was a marked performance benefit with the Enhanced HUD vice the Standard HUD. It was apparent that new display formats can result in significant improvements in recovering from unusual attitudes, thus addressing a vital safety of flight issue. Possible improvements in current HUD pitch ladder formats were suggested which would convey more cues to accurately and rapidly determine aircraft attitude, especially at negative pitch angles.

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INTRODUCTION

BACKGROUND

During the upgrade of the F-14 to the F-14D, pilots have expressed their concerns regarding the obscuration of the forward field-of-view due to the new Head-up Display (HUD) supports in conjunction with preexisting windscreen bows. The fact that the windscreen bows may hinder enemy aircraft detection, has led to the recommendation that a clear windscreen design, similar to the F/A-18, be considered as a replacement for the current windscreen. What effect the obscuration has on operational performance has not been systematically investigated.

An additional issue with the F-14 upgrade involves the proposed use of the HUD as the primary flight reference instrument. The attitude directional indicator (ADI) is currently the conventional flight reference system used for civil and most military aircraft. The ADI provides an artificial horizon allowing the pilot to assess pitch and roll of the aircraft without referencing the earth's horizon. Color coding is used to differentiate pitch attitude above and below the horizon. Thus, the design of the ADI follows the display principle of pictorial realism in that it represents a spatial analog of the real world[1]. Direct comparison between the display and the real world is not possible with symbolic displays such as the HUD. In fact, previous research has criticized the use of HUDs as primary flight reference instruments and as aids to recovering from unusual attitudes[2]. Reference 2 compared a HUD pitch ladder to an ADI for time to recover from unusual attitudes. Results showed that decision times for the ADI were significantly faster than the pitch ladder. Reference 3 compared an electronically-drawn ADI with the HUD and found results which paralleled those found by Reference 2. Reasons for the significantly faster recovery times for the ADI were attributed to the superiority of the color coding of the ADI for sky and ground over the dashed and solid pitch lines used for ground/sky coding on the HUD format.

In general, the HUD pitch ladder has been criticized for not providing enough information to enhance recovery from unusual attitudes[4]. Inadequate or ambiguous attitude displays in the cockpit pose serious problems and have been identified as contributing to numerous aircraft mishaps where loss of situational awareness or spatial disorientation were listed as confirmed or probable cause factors[5]. An alternative explanation for the HUD's inability to aid recovery asserts that it is not so much the *lack* of information displayed, but rather, the *format* in which it is presented. Reference 6 discussed various HUD pitch ladder formats in terms of the cognitive processes involved in assessing attitude. Pitch and roll indications on various HUD formats are complex multi-dimensional stimuli. Improving these formats, by incorporating redundant cues for example, may greatly reduce cognitive processing of information for assessment of attitude.

The purpose of the present study was twofold: (1) to measure the levels of "target" detection with and without windscreen bows; and (2) to measure unusual attitude recovery performance using two different HUD pitch ladder formats. For this purpose, a standard HUD format was compared with an enhanced HUD configuration developed at the Naval Air Development Center.

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METHODOLOGY

SUBJECTS

Twelve volunteers were used as subjects for the present study. Ten subjects were pilots currently on active duty with F-14A, F-14A+, or F-14D experience; one was on active duty with A-6/A-7 experience; and one subject was a retired pilot with F/A-18 experience. F-14 flight hours ranged from a low of 190 to a high of 2,000. Total flight hours ranged from 975 to 3,500. Two pilots had previous experience in the dynamic flight simulator (DFS). All but the A-6/A-7 pilot had experience in flying with a HUD.

PROCEDURE

The study began with a practice simulator flight which exposed the subject to all of the methods and conditions used during the primary study. Subjects were then required to fly using either a standard HUD or the enhanced-HUD format (see Figure 1). As represented in Figure 1, the enhanced HUD included the use of "sawteeth" rather than dotted lines at negative pitch attitudes. Smaller sawteeth would appear at 30° negative pitch and increase in size at 60° negative pitch. Moreover, the enhanced HUD configuration included horizon pointing tails at the inner ends of the pitch lines. Subjects were required to fly with either the windscreen bows on or off. A balanced experimental design was thus achieved by employing a Latin square design resulting in four experimental profiles employing one of four combinations of bows (on/off) and HUD format (standard/enhanced). Each profile consisted of six segments referred to as "maneuvers" which dictated a specific commanded heading, altitude, airspeed, pitch, and roll. During each maneuver, five targets were pre-programmed to appear at randomized locations, orientations (aspects), and times. To quantify and control the position of the target, the forward field-of-view (FOV) was divided up into a series of imaginary grids. Exposure of the pilot to the target began by the random placement of the target at various grid locations in the pilot's forward FOV at an initial range (15,000 feet). The target remained fixed at this grid position (which is relative to the pilot's eyepoint) regardless of aircraft maneuvering. At a fixed-time interval (every 2 seconds), the target size would increase by a fixed amount (1,100 feet) simulating the closing range of a threat coming towards the aircraft. This continued until either the target crossed a minimum-range threshold (1,800 feet), or the pilot indicated target detection. Target detection was considered to be the first instant that the pilot detected a target to be in the FOV and was indicated verbally and with a trigger pull. To indicate trigger pull to the pilot and investigators, visual feedback was provided in the form of a large "X" appearing on the HUD. The target was automatically removed from the display if: (1) the target moved in closer than the minimum threshold; (2) target identification confirmation was recorded; or (3) the command indicating end of maneuver was received. Detection time and range was then recorded by the computer.

In between each maneuver segment, the pilot was requested to go "head down" for a total of five times for each HUD configuration. At this point, the simulation was commanded to achieve a random, pre-programmed unusual attitude from a choice of nine different pitch/roll attitude combinations which simultaneously commanded the visual display and instruments to "freeze" at their current conditions (to avoid peripheral indications as to the direction of the unusual attitude). Once the unusual attitude was achieved, the display and instruments were updated to reflect the current aircraft attitude. The subject was then instructed to return to head-up and recover the aircraft. Unusual attitude recovery time was automatically computed based on specific recovery criteria shown in Table 1. Following recovery, the pilot was instructed to return to the flight conditions of the just completed maneuver in preparation for the next maneuver. After all profiles were completed, subjects completed a Debriefing Questionnaire.

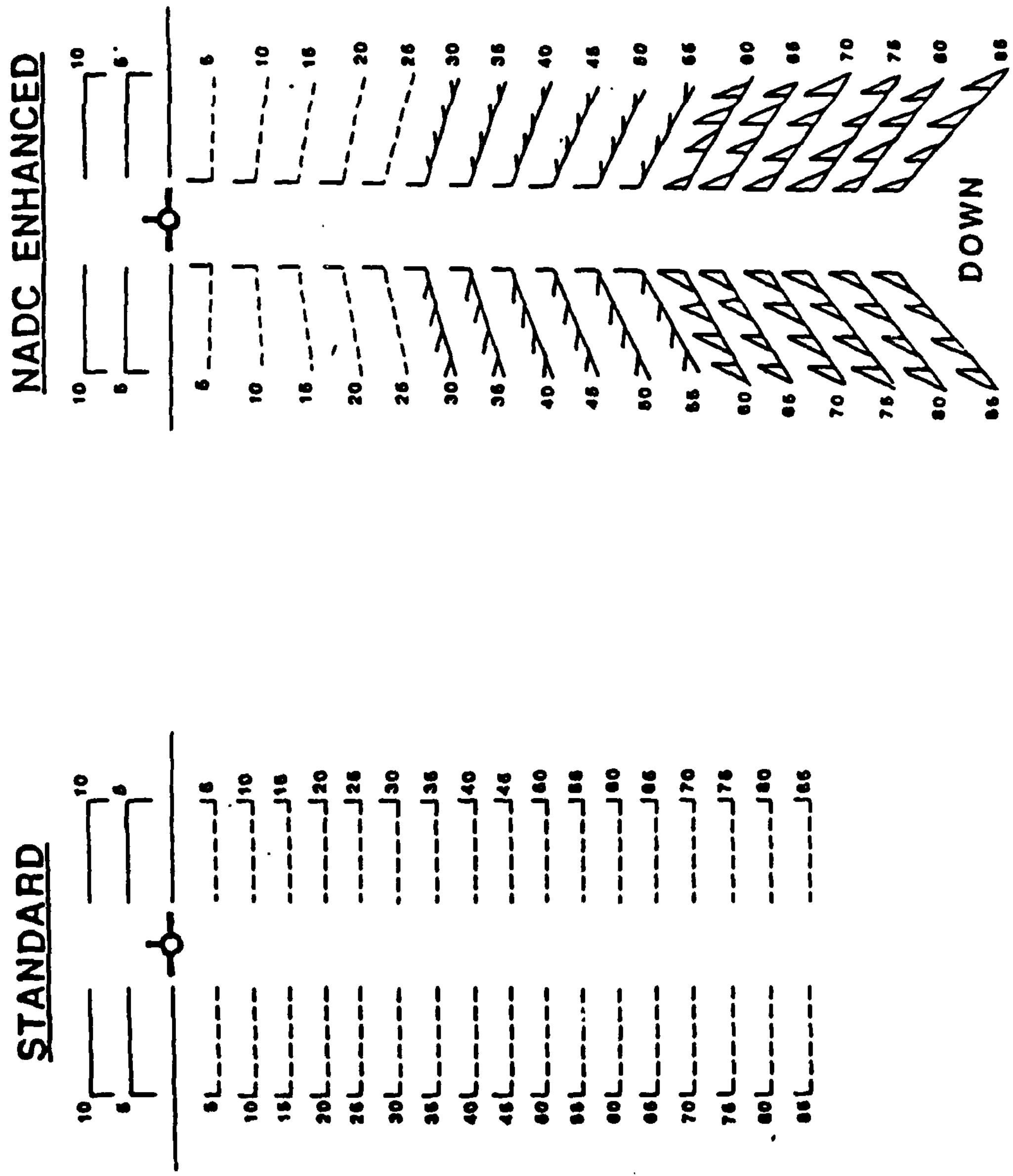

Figure 1. Standard and Enhanced HUD Formats.

RESULTS AND DISCUSSION

HUD DISPLAY

Data consisted of time to recover aircraft based on the criteria outlined in Table 1. These data were submitted to a 9 × 2 (pitch/roll combination × HUD configuration) analysis of variance with repeated measures on both factors. The overall analysis of variance (ANOVA) revealed a significant main effect for unusual attitude configuration ($F(8, 64) = 10.80$, $p < 0.001$). In addition, the unusual attitude x HUD configuration interaction effect was significant ($F(8, 64) = 4.22$, $p < .001$). Tests of the simple effects of HUD format for each unusual attitude configuration revealed a significant HUD effect for unusual attitude #3 [(–35° pitch/0° roll), ($F(1, 8) = 14.72$, $p < .01$)], unusual attitude #4 [(–35°/30°), ($F(1, 8) = 17.44$, $p < .01$)], unusual attitude #5 [(0°/30°), ($F(1, 8) = 9.47$, $p < .05$)], and unusual attitude #9 [(–65°/150°), ($F(1, 8) = 6.93$, < 0.05)]. Figure 2 shows unusual attitude recovery performance for each of the nine pitch/roll configurations. Considering only the cases in which a significant difference was reported between Standard and Enhanced HUDs, with the exception of unusual attitude #5, the significant differences reported above resulted in faster recovery time for the Enhanced HUD.

While a difference between formats appeared at unusual attitude #2 (+35°/30°), this difference was not significant due to the variation in recovery techniques used by the pilots. For example, some pilots chose to simply "push" the nose down (negative Gz), while others took the aircraft through a 360° roll to maintain positive Gz. At the condition with –35° pitch and 150° roll, the performance difference between the two HUD formats was negligible. Similar results were obtained for unusual attitudes that included only roll (120° and 180°). The Enhanced HUD was only marginally superior in these two cases.

The marked performance benefit of the Enhanced HUD was particularly apparent at severe negative pitch attitudes. This was to be expected since the design of the Enhanced HUD included features which were apparent only at negative pitch angles (the sawteeth). The major performance difference between HUD configurations occurred at the condition with –65° nose down pitch and 150° right roll (nearly inverted). With the Enhanced HUD, recovery times were 24 percent shorter than with the Standard HUD. At the two conditions with –35° nose down attitudes with little or moderate roll, the Enhanced HUD exhibited 20 percent and 26 percent shorter recovery times, respectively.

The overall difference in recovery performance for Enhanced versus Standard HUD format was less than 1 percent. This was misleading, however, due to the fact that much of the unusual attitude data was acquired for conditions at which one should not expect much improvement in recovery performance due to the Enhanced HUD. That is, in situations involving little roll or positive pitch, there is little reason to believe that the Enhanced HUD would be of benefit. These particular configurations were included in the study primarily to serve as baseline data in which to compare performance obtained in negative pitch situations. For those conditions where the Enhanced HUD might be expected to show some performance gains, e.g., –35°/0°, –35°/30°, and –65°/150°, the Enhanced HUD demonstrated significant improvements in recovery times on the order of 24 percent.

In terms of questionnaire data, pilots rated the performance of the Standard HUD and the Enhanced HUD in its ease of determining aircraft attitude during routine maneuvering. On a scale of 0 (Very Easy) to 10 (Very Difficult), subjects rated the Enhanced HUD and Standard HUD as 3.33 and 4.25, respectively. For assisting in recovering from unusual attitudes, the HUD's were rated on a scale of 0 (Little Help) to 10 (Very Helpful). The Standard HUD was rated at 5.25 (Moderate Help), while the Enhanced HUD was rated at 7.5. This 25 percent higher rating indicates that the pilots felt the Enhanced HUD to be superior in assisting them in recovering from unusual attitudes. When asked to

Table 1. Unusual Attitude Recovery Criteria.

PARAMETER		CRITERIA
ALTITUDE	>	0 FEET
AIRSPEED	>	180 KNOTS
BANK ANGLE	<	30 DEGREES

THE PITCH AND VERTICAL VELOCITY CRITERIA WERE CONTINGENT ON THE INITIAL COMMANDED PITCH ATTITUDE:

	INITIAL U.A. PITCH ATTITUDE		
	NEGATIVE	0	POSITIVE
PITCH (DEG)	> -10	< 10	< 10
VERTICAL VELOCITY (FT/MIN)	> -100	> -100	< 1200

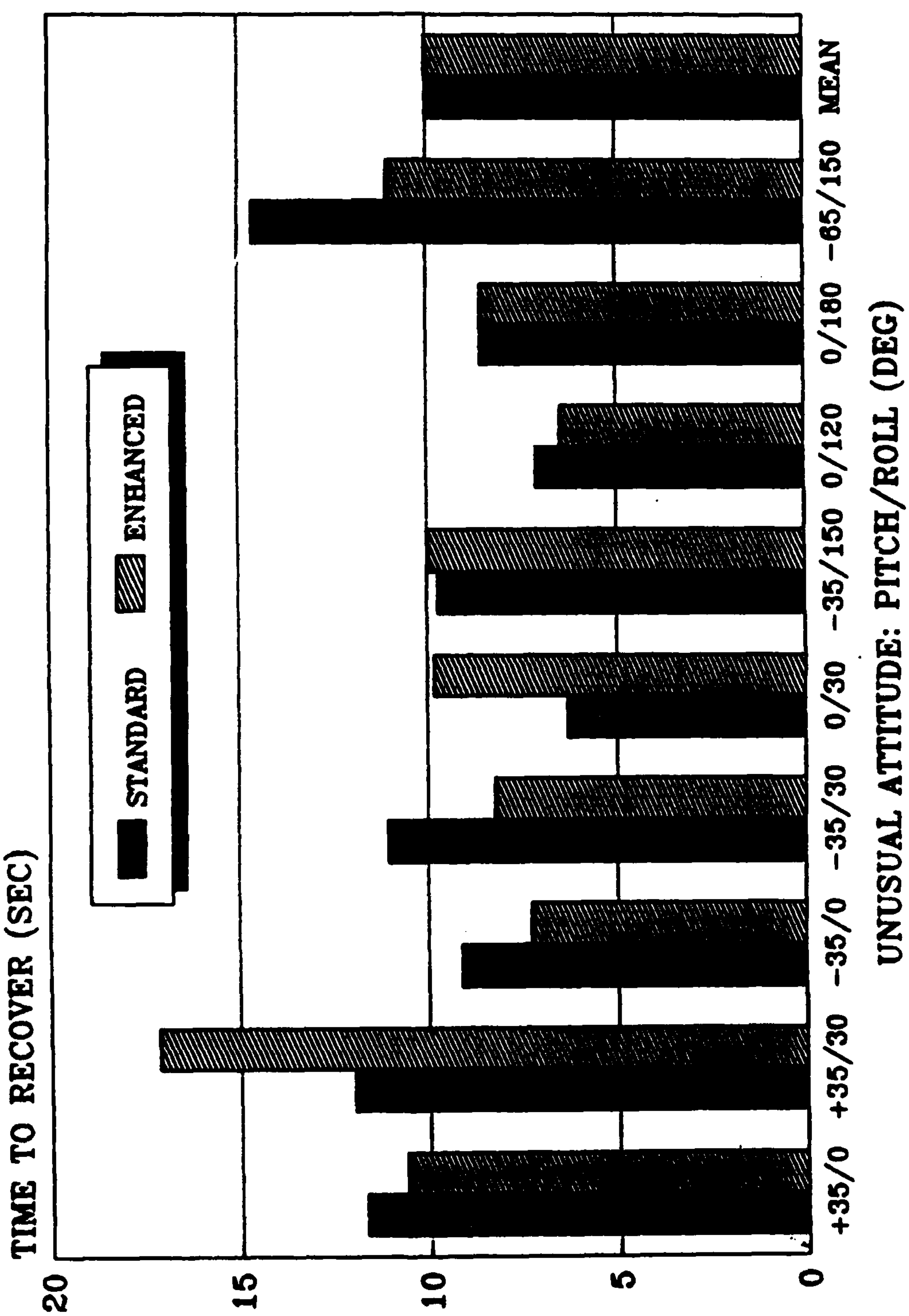

Figure 2. Unusual Attitude Recovery Performance for Each Unusual Attitude Configuration.

choose a HUD preference for routine and emergency/misoriented flight, the results showed that only one pilot selected the Standard HUD. Ten pilots chose the Enhanced HUD while one subject indicated no preference.

WINDSCREEN BOWS

The dependent variables examined to analyze the effects of windscreen bow obscuration were the range at which the targets were detected, and the time-to-detect each target. Figure 3 shows the percentage of target detection versus target detection range. According to Figure 3, 59 percent of the targets were detected at the initial range with the windscreen bows removed. This is almost double the value of 32 percent detected at the initial range when the windscreen bows were installed. Though this ratio of nearly 2:1 is not maintained as range decreases, the effect of the windscreen bow on ability to detect targets persists to the point where the targets are automatically removed from the visual display and a "miss" is recorded.

Figure 4 shows the effect of windscreen on percentage of target detection as a function of target detection time. The overall ANOVA associated with average time to detect targets revealed a significant effect for windscreen bows ($F(1, 7) = 16.90$, $p < 0.01$). More specifically, within the first five seconds, 80 percent of the targets were detected with the bows off, while only 60 percent were detected with the bows on. This represents approximately a 33 percent improvement in the ability to detect targets with removal of the windscreen bows.

Questionnaire data for the obscuration portion required pilots to rate the degree to which the windscreen bows obscured the forward FOV in their aircraft and in the DFS. Results indicated that the pilots felt that the DFS matched the level of obscuration in the actual aircraft (32 percent and 31.7 percent obscured ratings were reported for their aircraft and the DFS, respectively). The obscuration, due to the HUD supports, was rated as 10 percent.

Results clearly supported the recommendation for removal of the windscreen bows. In addition, it was apparent that new display formats can result in significant improvements in recovering from unusual attitudes.

POSSIBLE HUD FORMAT ENHANCEMENTS

There have been numerous suggestions for changing HUD format configurations. The most promising recommendations have been made by an Air Force study.[4] The results of this study have shown that a 2:1 pitch-scale compression ratio is advantageous in recovering from an unusual attitude. Moreover, additional bank information and an upward pointing cue (Augie Arrow) on the velocity vector has been shown to be effective. The appearance of the Augie Arrow should be automatic whenever some attitude parameters are exceeded. For example, whenever pitch exceeds plus or minus 8° or 40° angle-of-bank, the Augie Arrow would be enabled. Using this algorithm removes the Augie Arrow from the display during most of the nearly level flight regimes. According to the Air Force study, automatic deletion of the velocity vector symbol at high angles-of-attack also enhances recovery.

Another format which is gaining in popularity is a pictorial display designed by Gilbert Klopfstein of the French Service Technique Aeronautique for use during instrument approaches. In brief, this display was designed under the assumption that it is easier to interpret glideslope and azimuth deviations from a drawing of the runway environment than from Instrument Landing System needles. The Klopfstein HUD has been implemented on some commercial aircraft HUD's and is used on the Navy A-6 Head-Down Display when the landing mode option is selected. In addition to the runway symbol, this format

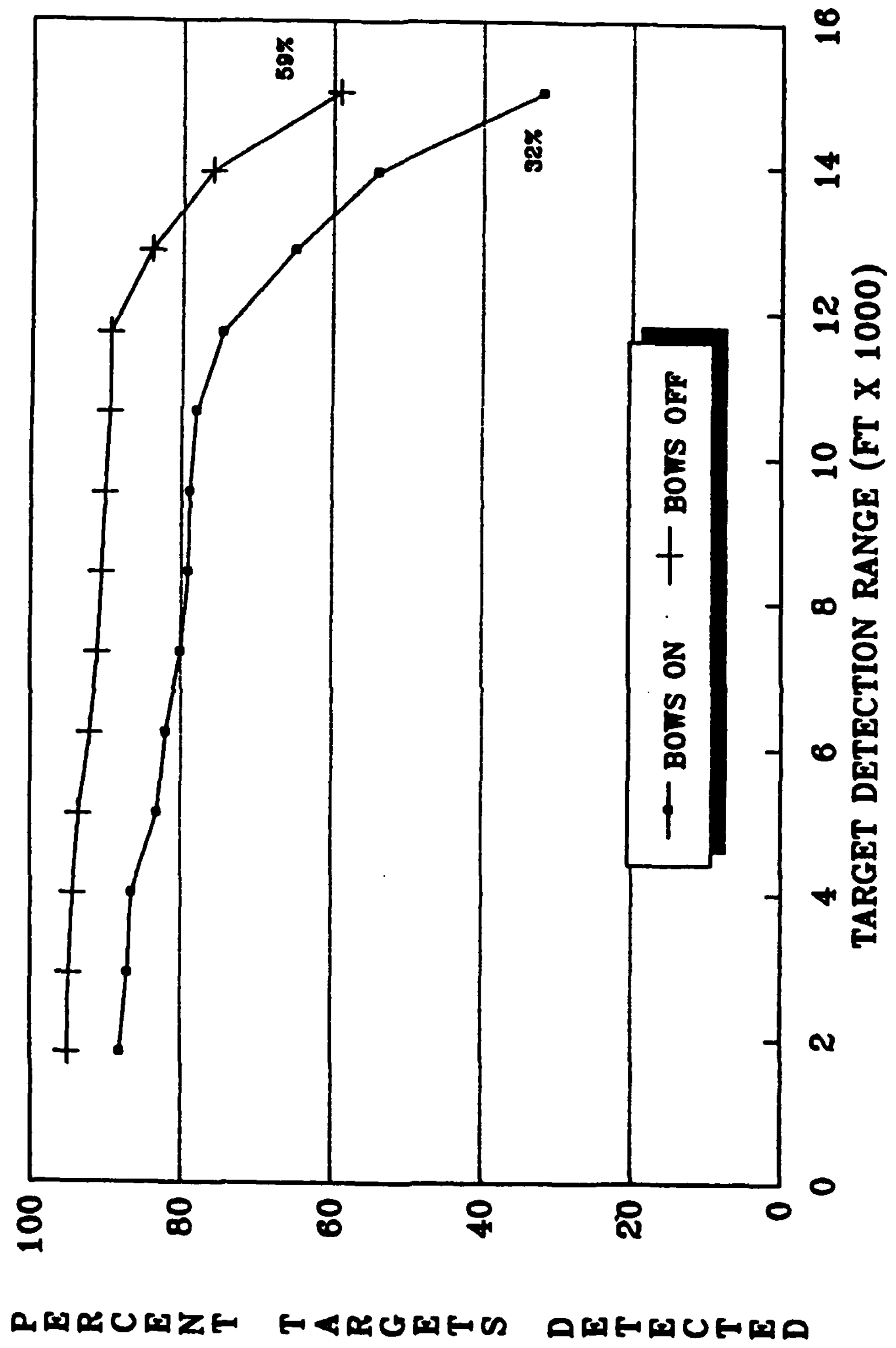

Figure 3. Effect of Windscreen Bows on Percentage of Target Detection as a Function of Target Range.

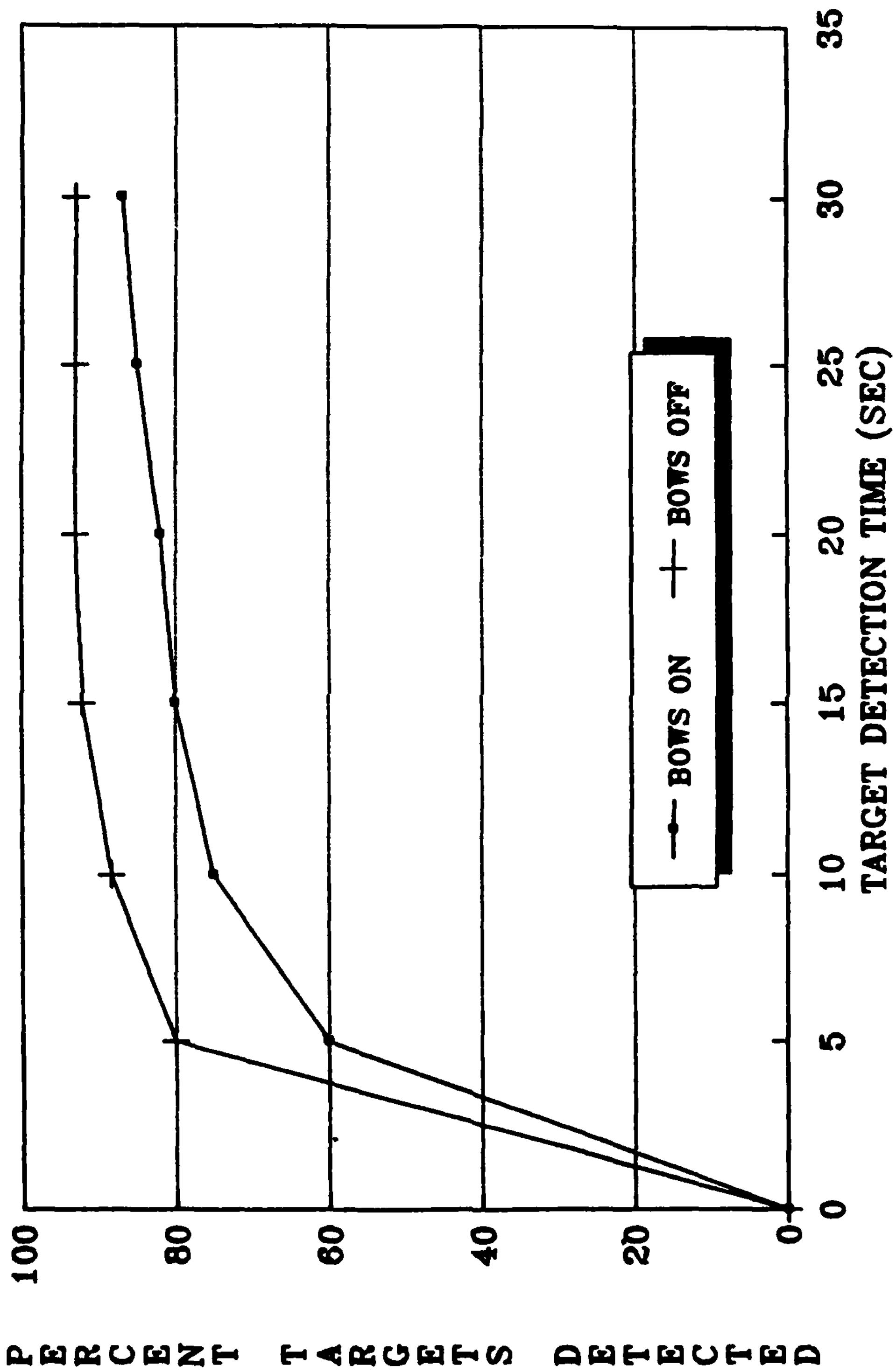

Figure 4. Effect of Windscreen on Percentage of Target Detection as a Function of Target Detection Time.

also includes flight-path angle, angle-of-attack, heading, and track-angle information. It is important to note that none of this information is presented using digital readouts. The usefulness of the Klopfstein HUD has not as yet been documented. However, the concept does have appeal in terms of displaying real-world cues (pictorial realism).

Other display methodologies have been suggested which enhance the rather poor three-dimensional spatial awareness characteristics of current HUDs.[7] One such approach is associated with the development of a textured standby attitude display. Attitude recognition is enhanced by a "full-ball display" (even though it may be very small — on the order of 30 mr). The "ground" of the display is textured rather than solid filled, preferably using a graduated horizontal and point perspective vertical field. The standby textured ball should be positioned down on the lower right of the HUD display. At this position it is unobtrusive but still available for immediate reference.

Numerous other design features have been suggested. The interested reader is encouraged to consult Reference 4 for examples of additional format recommendations. Clearly, modifications to HUD configurations can enhance recovery from unusual attitudes. The present study revealed that at severe negative pitch attitudes, there is a marked performance benefit with the Enhanced HUD used in this study compared to the Standard HUD. It is recommended that future investigations develop additional HUD pitch ladder format possibilities conveying more cues to accurately and rapidly determine aircraft attitude in order to enhance situational awareness.

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REFERENCES

1. Roscoe, S.N., Corl, L., & Jensen, R.S., Flight Display Dynamics Revisited, *Human Factors, 23*(3), 341–353, 1981.

2. Kinsley, S.A., Warner, N.W., & Gleisner, D.P., *A Comparison of Two-Pitch Ladder Formats and an ADI Ball for Recovery From Unusual Attitudes.* Naval Air Development Center (Report No. NADC-86012-60), 1985.

3. Guttman, J., *Evaluation of the F/A-18 Head-up Display for Recovery from Unusual Attitudes.* Naval Air Development Center (Report No. NADC-86157-60), 1986.

4. Newman, R., *Evaluation of Head-up Displays to Enhance Unusual Attitude Recovery.* Flight Dynamics Laboratory, Wright-Patterson Air Force Base, OH (Report No. AFWAL-TR-87-3055), 1987.

5. Kennedy, D., Better Attitude Displays for Enhanced Situational Awareness, *Approach, 15,* 25–32, 1987.

6. Taylor, R., *Some Effects of Display Format Variables on the Perception of Aircraft Spatial Orientation.* Presented at the NATO AGARD Medical Panel Symposium, Williamsburg, VA., 1984.

7. Hughes, R.E., *General Recommendations for Head-up Display Symbology for Fixed-wing Vehicles.* Naval Air Systems Command. Unpublished manuscript, 1989

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